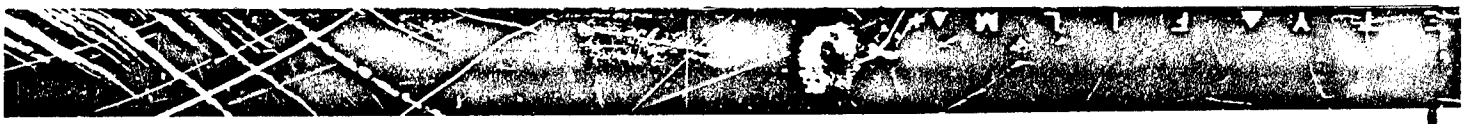
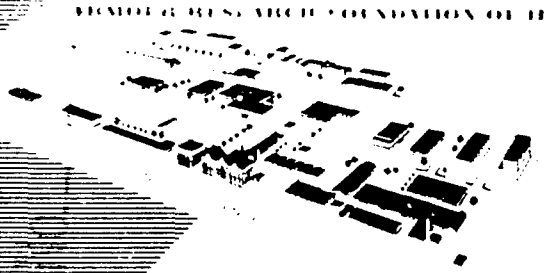
AD 289 258



NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

ARF 8249
Annual Progress
Report

TECHNOLOGICAL RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY



INVESTIGATION OF FOOTWEAR FOR PROTECTION AGAINST LAND MINES

by

J. L. MacDonald

for

Office of the Surgeon General
Washington 25, D. C.

November, 1962

RESEARCH FOR INDUSTRY

ARF 8249
Annual Progress
Report

ARF

ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY

INVESTIGATION OF FOOTWEAR FOR PROTECTION AGAINST LAND MINES

by

J. L. MacDonald

for

Office of the Surgeon General
Washington 25, D. C.

November, 1962

RESEARCH FOR INDUSTRY

Annual Progress Report

Covering the period
March 1962-October 1962

by
John L. MacDonald
Armour Research Foundation of
Illinois Institute of Technology

INVESTIGATION OF FOOTWEAR FOR PROTECTION AGAINST LAND MINES

DA-49-193-MD-2247

for
Office of the Surgeon Gereral
Washington 25, D. C.

Unclassified

ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY

TABLE OF CONTENTS

1. PRINCIPAL INVESTIGATOR

Mr. John L. MacDonald, Armour Research Foundation of Illinois Institute of Technology, is project engineer.

2. PROJECT TITLE

The program is entitled "Investigation of Footwear for Protection against Land Mines.

3. CONTRACT NUMBER

The work is being done under Contract DA 49-193-MD-2247, for the Office of the Surgeon General.

4. DATE OF REPORT

The first annual report is due on 1 December 1962 and the final report due at the expiration of the contract on 28 Feb. 1963.

5. REQUIREMENT AND JUSTIFICATION

The increased use of small anti-personnel land mines during World War II and the Korean conflict has indicated that a greater number of disabling lower extremity wounds can be expected in the event of future conflicts. The development of protective footwear to reduce or eliminate the severity of injury without affecting the efficiency or mobility of the wearer is the principal task of this program.

The successful development of footwear which would be resistant to the effects of anti-personnel mines will have the following results:

A. Maintain the psychological attitude and subsequent efficiency of the combat soldier when exposed to tactics employing anti-personnel mines.

B. Reduce the severity or degree of injury upon exposure to the blast effects of the mine.

C. Reduce or eliminate time loss from combat readiness.

D. Reduce the amount of support personnel (replacements, medical, QM, etc.) and logistics required to replace, care f.. and supply injured troops.

E. Reduce significant costs in the above as veteran disability benefits.

6. SUMMARY

A. Brief

While the final objective of this program effort is the development of protective footwear that is resistant to small anti-personnel mine blast effects, the solutions to a series of preliminary objectives must be available before a rational approach can be made towards a means of attenuating these effects.

One objective is to determine the degree of protection or attenuation which must be provided by the protective footwear. This objective is related to the damage threshold or capabilities of the foot to tolerate abrupt impulsive loadings and the physical characteristics of the exploding mine.

Accordingly, this program was established to provide a device which would simulate a controlled explosive environment to be used for the assessment of the damage threshold of an unprotected human foot.

The operation of the device and the damage assessment of the foot is the responsibility of the Office of the Surgeon General.

An additional objective of this program is the determination of the pressure-time and impulse generated by an anti-personnel mine. ARF was directed to use the M-14 anti-personnel mine for this investigation.

This effort (by OSG and ARF) will determine the input characteristics

of the mine to the attenuator system (protective footwear) and the capabilities of the foot to withstand the attenuated input.

A correlation of this information will determine the degree of attenuation desired from the protective footwear.

The construction of protective footwear concepts is included in a program current at ARF for the Quartermaster Engineering and Research Command Project No. DA-19-129-QM-2061(OI 6137). This program, partially funded, is to study material, and design configuration response to high rates of loading and to evolve design concepts for implementation into protective footwear.

The final validation of the protective concepts are to be assessed through the O. S. G. The validation will be performed by O. S. G. through a medical observation of damage after exposure of a cadavar leg encased in the protective footwear to the blast effects of the M-14 A. P. mine.

B. Approach

The approach of this program to the problem of evolving a protective footwear concept is to first establish the environment to which the footwear will be subjected. Second, by the capabilities of the unprotected human foot to withstand impulsive type loadings will also be assessed. Additional ARF contractural commitments with the QM Corps are to optimize the selection of materials and design configurations for incorporation into prototype design concepts. The prototypes are then to be evaluated with cadavar legs by exposure to the effects of the M-14 anti-personnel mine.

This approach differs considerably from other efforts to provide an effective protective concept. The previous work has been principally empirical in nature wherein a concept was conceived, implemented into a boot,

fitted with a leg simulant (gelatin, cadavar, etc.), exposed to the effects of detonating M-14 mine and the damage assessed by medical observers.

The principal differences in the two methods of approach lie in the control of experimental parameters and the capability of optimizing materials and design configurations on the basis of predictable or measurable response, while the empirical approach depends entirely upon the ingenuity of the inventor and the evaluation of blast effects by opinion. The empirical approach is also detramentally influenced by inherent physical variations in cadavar leg simulants during the development of a protective concept.

C. Background History and Progress

1. Background history.

A considerable amount of effort has been expended in the field of protective footwear concepts. The results of this effort has resulted in two general types of protective concepts. One type being a sabot of additional sole which is strapped to the conventional shoe and the other type incorporating the attenuating device within a molded boot.

The sabot type furnishes the greatest degree of protection but presents considerable problems in mobility and logistics.

The molded boot attenuator investigation is presently being conducted. The results of this effort indicate that same attenuation is possible but a question remains as to the maximum attenuation which can be attained. The main problems that have confronted investigations in this field has been the evaluation of response to a closely controlled experimental environment and the lack of data for the dynamic response of the human foot to impulsive loadings.

The present program will provide equipment and data to obviate this problem.

2. Progress

Activity on the subject program has been directed along two lines during the current report period; namely a) design of a loading device to provide simulated pressure and impulse produced by a small anti-personnel land mine and b) the determination of the pressure distribution in the vicinity of an M 14 anti-personnel mine. Each of these two activities will be discussed individually below:

Loading Device

Most of the work performed on this task during the current report period centered about a literature review of topic related to the design of the loading device, free air blast data, protective footwear concepts, and personnel injury effects. References covered in this review (20) are given in section E of this report. A complete review of the literature survey will be presented in the fianl report on this project.

Initial design studies indicate that pressure generated by an exploding M-14 mine can best be simulated by employing an explosively driven loading device. Since this device will be employed as a research tool it must operate over a wide range of both pressure and impulse. For this reason two different driven sections must be employed. The first will house a point source charge and will provide the energy required for the higher reflected pressure (those in excess of about 4,000 psi). For lower pressure a second detonation chamber will be constructed

to accomodate a distributed charge (prima cord). With both systems the pressure and impulse in the test section can be controlled by the length of the tube and the size of the explosive charge. Tentative data showing the reflected pressure and impulse produced by the loading device as a function of tube length and explosive charge is shown in Figure 1. For the point source detonation chamber intersection of the charge weight curves with the tube length curves give the reflected pressure and impulse obtained from the set of tube parameters.

Also superimposed on Figure 1 is a damage effect curve constructed from preliminary data presented by Stewart[15]. This curve represents a first approximation of the damage threshold of the human foot. The results obtained by employing the loading device will permit a more accurate determination of this curve.

Currently design drawings are being prepared for the explosively driven loading device. Engineering drawings will cover the four major components of the system.

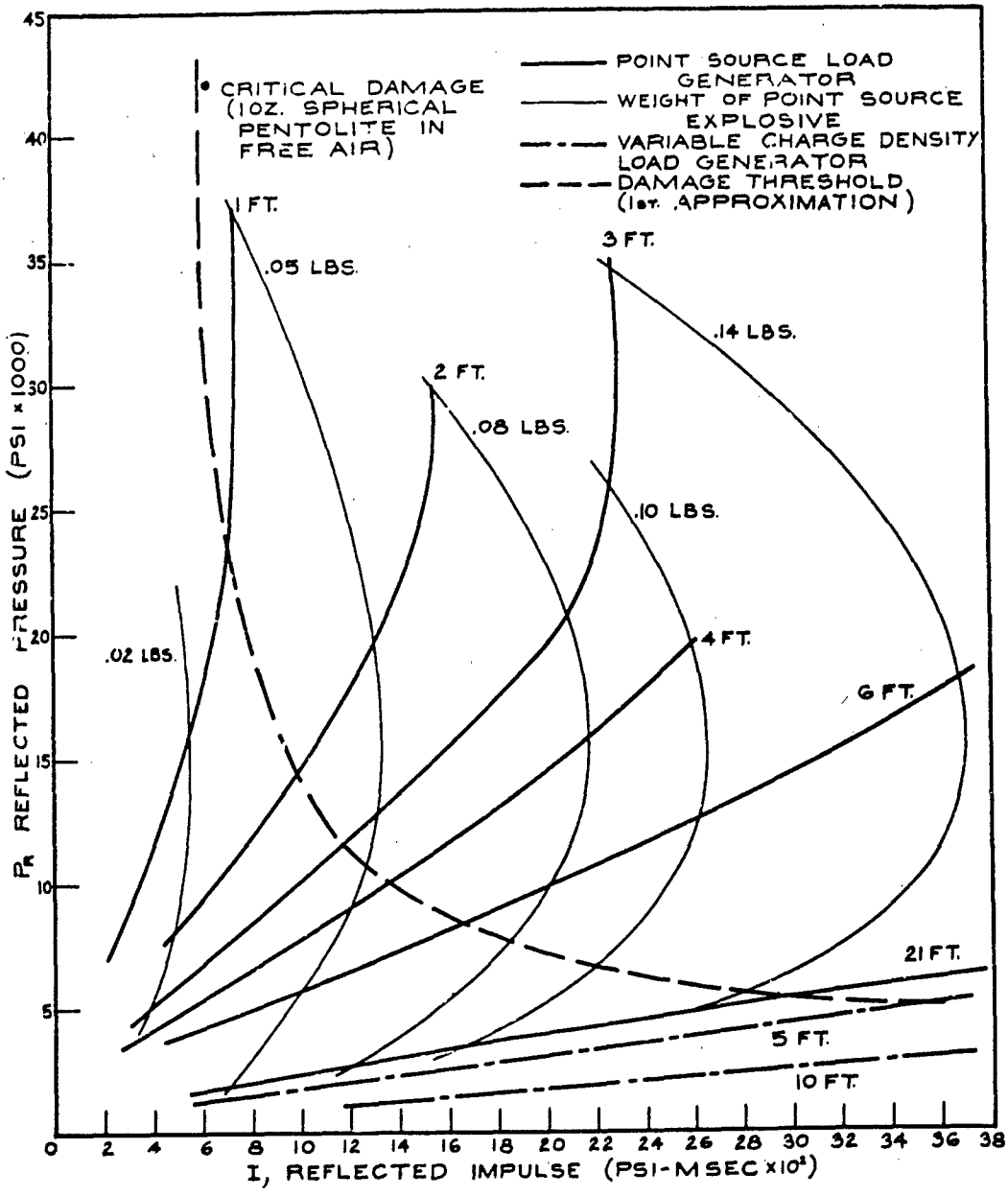
(1) Detonation Chamber

(2) A series of heavy walled tube sections

(3) A pendulum mounted test section

(4) The necessary support structure

In operation the charge and tube length will be selected to provide the specified pressure and impulse loading. The tube is assembled, the charge placed and test specimen mounted on the pendulum. The loading is accomplished immediately upon detonation of the charge. Records of the side on pressure will be made with a Kistler pressure transducer.



LOADING DEVICE OPERATING RANGE

(REFLECTED PRESSURE VS IMPULSE AT VARIOUS TUBE LENGTHS AND CHARGE WEIGHTS)

The impulse imparted to the system will be determined by measuring the total displacement of the pendulum. Upon completion of a test shot the pressure and impulse records will be analyzed and medical observations will be made by the O. S. G. on the damage incurred by the test specimen.

Measurement of the surface pressure time relationship of the M-1 Anti-Personnel mine.

Twenty-five M 14 A. P. mines were obtained from the Ordnance Ammunition Command in Joliet, Illinois to be employed to establish the surface pressure time relationship. These experiments are currently in progress and preliminary results indicate that the average surface pressure of the mine is approximately 40 kilobars* for the first microsecond after detonation is initiated.

The technique used for the surface pressure measurements follows from the work of Hopkinson. A series of small diameter metal discs of different thicknesses are placed on the surface of the mine. Upon detonation these discs are driven off the mine and their motion is observed with an ultra high speed framing camera (4, 300, 000 frames/sec). Analysis of the photographic records provides the time displacement history of the discs ("flyer plates"). This data is then used with the mechanical impedance characteristics of the mine and flyer plates to determine the pressure-time relation at the surface of the mine. Technical

*Kilobar = 15, 000 psi

difficulties encountered in the use of the ultra high speed camera have delayed completion of this task. However, these difficulties have been resolved and the task should be completed in the very near future

D. Future Plans

The completion of the present contractual commitments for O. S. G. is expected to follow the schedule outlined below.

The M-14 mine characteristics of peak pressure and total impulse will be completed by January 1, 1963.

The design of the loading device will be completed by December 15, 1962.

The manufacture of the loading device will be complete by February 1, 1963.

The setup and indoctrination of personnel in the use of the loading device is anticipated for the last two weeks of February.

A tentative test procedure will be written and included with the final report on or before the February 28, 1963 termination date of the contract.

The necessity of providing an explosively driven loading device rather than a mechanical or hydraulically powered device will require additional instructional effort by ARF to the eventual user. This additional effort was not anticipated in the original proposal and will consist of the design of explosive components and a more complicated calibration procedure.

A continuing effort for O. S. G. is also anticipated by ARF where in we will participate in the analysis of the test results in cooperation with the agency appointed to conduct the damage threshold program.

ARF feels that our participation is mandatory to provide overall program continuity in the evolution of protective footwear concepts.

ARF will submit, if desired by O. S. G., a request for a time and cost extension which will permit our continuing active participation on the program.

Respectfully submitted,

ARMOUR RESEARCH FOUNDATION OF
ILLINOIS INSTITUTE OF TECHNOLOGY

J. L. MacDonald, Manager
Mechanism Laboratory

APPROVED:

J. W. Dally, Assistant Director
Mechanics Research

E. REFERENCES

1. Barr, Capt. J. S., Draeger, Capt. R. H., Sager Cmdr. W. W. Solid Blast Personnel Injury: A Clinical Study "The Military Surgeon", Vol. 98, No. 1 January, 1946

2. Buchanan, J. S. and James H. J. Measurement of High Intensity Stress Pulses. "British Journal of Applied Physics". Vol. 10, June, 1959.

3. Coermann, R. R., et. al. The Passive Dynamic Mechanical Properties of the Human Thorax-Abdomen System and of the Whole Body System. "Aerospace Medicine". Vol. 31, No. 6, June, 1960.

4. Dempster, W. T. and Liddicoat R. T., Compact Bone as a Non Isotropic Material. "The American Journal of Anatomy." Vol. 91. No. 3 November, 1952

5. Gibson, F. C. et. al. Initiation of Detonation Resulting from Combustion Instabilities. Explosives Research Laboratory, Bureau of Mines Pittsburgh, Pa., July, 31, 1962.

6. Goodman, H. J. Compiled Free Air Blast Data on Bare Spherical Pentolite. BRL Report No. 1092. Ballistics Research Laboratory. February, 1960.

7. Harris C. M. and Crede C. E. Effects of Shock and Vibration on Man. "Shock and Vibration Handbook" Chapt. 44 Vol. 3. McGraw Hill Book Co., New York, 1961.

8. Holland, L. R. A Method For Obtaining the Force-Time Relationships of Certain Explosive Ordnance. Naval Medical Field Research Lab., April, 1955.

9. Hoomes, Col. Robert H. et. al., Preliminary Evaluation of the Experimental Shank Direct Molded Sole Boot Against the M-14 Land Mine. CWL Technical Memorandum 21-3, Biophysics Division, U. S. Army Chemical Warfare Laboratories, April, 1960

10. Johnson, O. T. et. al. A Simple Mechanical Method for Measuring the Reflected Impulse of Air Blast Waves. BRL Report 1088. Ballistics Research Laboratories, July, 1957.

11. Jordan, LTJG R. D. A Device For Protecting the Lower Extremities From the Blast Forces of Small Anti-Personnel Mines. Naval Medical Field Research Laboratories, March, 1956 (Confidential)

References (continued)

12. Leopold, CDR R. S. The Action of Anti-Personnel Mines Across a 4-Inch Air Gap. Technical Note Vol. XI, No. 16. U. S. Naval Medical Field Research Laboratory, September, 1961.

13. Lewis, LCDR F. J. and Quinlan J. F. The Protective Qualities of the Thermal Boot Against Explosive Ordnance. Naval Medical Field Research Lab., June, 1952.

14. Rinehart, J. S. Experimental Determination of Stresses Generated by an Electric Detonator. "Third Symposium on Detonation", ONR Symposium Report ACR-52, Vol. 1. Office of Naval Research, Sept. 26-28, 1960.

15. Stewart, George M. Untitled, Unpublished Data on the Blast effect of Various Charge sizes and configuration against Human Lower Extremities., Body Armor Branch, Biophysics Division, Directorate of Medical Research, U. S. Army Chemical Research and Development Laboratory.

    26 September 1962 (Letter)
    5 September 1962 (Letter)
    9 August 1962 (Letter)
    27 June 1962 (Letter)
    7 June 1962 (Letter)
    18 May 1962 (Letter)
    27 March 1962 (Data Notes)

16. "Effects of Impact and Explosion", Summary Technical Report of Division 2, NDRC, OSRD, Vol. I, 1946, Conf.

17. "The Air Force Shock Tube as a Research Tool", by T. H. Schiffman, Proceedings of First Shock Tube Symposium, Feb., 1957.

18. "NOL Model Nuclear Air Blast Simulation", by W. S. Filler Proceedings of Fourth Shock Tube Symposium, April, 1961.

19. "Volume Detonation in Shock Tubes, " by J. J. Swatosh and A. H. Wiedermann, Proceedings of Fourth Shock Tube Symposium April, 1961.

20. "Feasibility Study for a Large Blast Simulator", Final Report, Armour Research Foundation Contract No. DA-49-146-XZ-064, June, 1962.

DISTRIBUTION LIST

4 copies	Commanding General U. S. Army Medical Research and Development Command Main Navy Building Washington 25, D. C. ATTN: Chief, Reports Branch
10 copies	Armed Services Technical Information Agency Arlington Hall Station Arlington 12, Virginia
1 copy	Commanding Officer USAMEDS Combat Development Group Brooke Army Medical Center Fort Sam Houston, Texas
1 copy	Quartmaster Research and Engineering Command Textile and Organic Division Natick, Massachusetts ATTN: Mr. Edward Barron
1 copy	Medical Directorate Biophysics Division Chemical Corps Research and Development Laboratories Army Chemical Center, Maryland ATTN: Mr. George Stewart
1 copy	Ballistics Research Laboratory Terminal Ballistics Section Aberdeen Proving Ground, Maryland ATTN: Mr. L. Hoffman
1 copy	Commanding Officer Medical Equipment Development Laboratory Fort Totten, Flushing 59 Long Island, New York
1 copy	Director Walter Reed Army Institute of Research Walter Reed Army Medical Center Washington 12, D. C. ATTN: Surgical Research Division
1 copy	Development and Proof Service Aberdeen Proving Ground, Maryland ATTN: Mr. James White

Distribution List (continued)

1 copy	Mr. John L. MacDonald Armour Research Foundation of Illinois Institute of Technology 10 W. 35th Street Chicago 16, Illinois
1 copy	Dr. Harry Jackson Reynolds Metals Co. P. O. Box 2346 Richmond, Virginia
1 copy	Martin S. Litwin Captain M. C. Surgical Research Branch U. S. Army Medical Research and Development Command

U. S. Army Medical Research and Development Command Department of the Army, Washington 25, D. C.
DA-49-193-MD-2247. INVESTIGATION OF FOOTWEAR FOR PROTECTION AGAINST LAND MINES Annual Progress Report Nov. 62, 13p., Unclassified report.

This program is the preliminary phase for the development of protective footwear concepts. The program differs in its approach to previous work in the field in that design prototypes of protective footwear will be based upon knowing the degree of the attenuation they must provide rather than grossly assessing design concepts.

(over)

I John L. MacDonald
II Armour Research Foundation of Illinois Institute of Technology, Chicago 16, Ill.
III Contract No. DA-49-193-MD-2247
IV U. S. Army Medical Research and Development Command Department of the Army, Washington 25, D. C.

To attain this information a loading device will be provided and the pressure-time characteristics of an M-14 Anti-Personnel mine will be measured. A description of an explosively driven loading device to investigate the response of leg simulants to blast pressure is described. A graphical presentation of the devices operating parameters is also presented. The initial results of a modified Hopkinson technique to establish the surface pressure of an exploding M-14 Anti-Personnel mine are also presented.

U. S. Army Medical Research and Development Command Department of the Army, Washington 25, D. C.
DA-49-193-MD-2247. INVESTIGATION OF FOOTWEAR FOR PROTECTION AGAINST LAND MINES Annual Progress Report Nov. 62, 13p., Unclassified report.

This program is the preliminary phase for the development of protective footwear concepts. The program differs in its approach to previous work in the field in that design prototypes of protective footwear will be based upon knowing the degree of the attenuation they must provide rather than grossly assessing design concepts.

(over)

I John L. MacDonald
II Armour Research Foundation of Illinois Institute of Technology, Chicago 16, Ill.
III Contract No. DA-49-193-MD-2247
IV U. S. Army Medical Research and Development Command Department of the Army, Washington 25, D. C.

To attain this information a loading device will be provided and the pressure-time characteristics of an M-14 Anti-Personnel mine will be measured. A description of an explosively driven loading device to investigate the response of leg simulants to blast pressure is described. A graphical presentation of the devices operating parameters is also presented. The initial results of a modified Hopkinson technique to establish the surface pressure of an exploding M-14 Anti-Personnel mine are also presented.